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RESEARCH ARTICLE

The Effect of Obesity on Pulmonary Function among Healthy Non-smoking Adults

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ABSTRACT

Background: Obesity is a chronic disease characterized by the excessive accumulation of body fat which is associated with comorbidities. It is a growing health issue worldwide. Obesity is known to have significant effects on respiratory function and obese patients commonly report respiratory complaints requiring pulmonary function tests. **Objectives:** The objectives of the study were to determine the effects of obesity on pulmonary function in overweight and obese adults who were non-smokers and did not have any respiratory diseases. **Materials and Methods:** This cross-sectional study was carried out among 181 healthy adults of both sexes between 20 and 60 years, those attended master health check-up and medicine outpatient department. The study participants were divided into three body mass index (BMI) groups according to the WHO BMI classification. Forced vital capacity in liters (FVC), forced expiratory volume in the first second in liters (FEV1), FVC/FEV1, peak expiratory flow rate in liter/min (PEFR), and forced expiratory flow (FEF)25–75% were recorded. These three BMI groups were compared using one-way ANOVA, correlation was assessed by Pearson's "r." Linear regression analysis was applied. **Results:** Significant differences in lung volumes were found in three BMI groups. Obese and overweight subjects had significantly lower FVC, FEV1, FEF25%–75%, and PEFR ($P < 0.0001$) as compared to normal weight subjects. However, there was no statistically significant difference found in FEV1/FVC ratio. There were significant linear relationships between obesity and pulmonary function. BMI had significant negative linear association at the level of $P < 0.001$ with FVC% ($r = -0.355$), FEV1% ($r = -0.361$), FEF25%–75% (−0.432), and PEFR ($r = -0.501$). FEV1/FVC ratio was negatively correlated, but statistically not significant. **Conclusion:** BMI has a detrimental effect on pulmonary functions in overweight and obese subjects. Reduction in FVC and FEV1 was the most representative findings among the overweight and obese subjects, suggesting the presence of a restrictive respiratory pattern associated with obesity. It might be due to decrease in lung and chest wall compliance and increase in work of breathing.

Keywords: Adults, body mass index, compliance, obesity, pulmonary function test, spirometry

INTRODUCTION

Obesity is one of the world's largest health problems. It has shifted from being a problem in rich countries and become a health problem which spans all income levels. Obesity in adults is defined by the World Health Organization (WHO) as having a body mass index (BMI) that is greater than or equal to 30 kg/m^2. Obesity is a risk factor for several of the world's leading causes of death, including heart disease, stroke, diabetes, and various types of cancer. Obesity does not directly cause of any of these health impacts but can increase their likelihood of occurring.[1] Globally, 13% of adults aged 18 years and older were obese in 2016 and 39% of adults aged 18 years and older were overweight or obese in 2016. The WHO reports that the share of children and adolescents aged 5–19 who are overweight or obese has risen from 4% in 1975 to around 18% in 2016.[2]

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According to the Global Burden of Disease study, 4.7 million people died prematurely in 2017 as a result of obesity.[3] To put this into context: This was close to 4 times the number that died in road accidents, and close to 5 times the number that died from HIV/AIDS in 2017.[1]

Obesity is a chronic condition characterized by excessive body fat that causes damage to the individual's health and is associated with comorbidities such as diabetes and hypertension and vascular dysfunction.[4,5] Some of the respiratory symptoms commonly associated with obesity include wheeze, dyspnea, and orthopnea are also increased as BMI increases.[6]

Obesity is an important risk factor and disease modifier of many respiratory conditions such as asthma,[7] chronic obstructive pulmonary disease,[8] obstructive sleep apnea, and obesity hypoventilation syndrome. The epidemic of obesity has increased the prevalence and morbidity, and altered the clinical presentation of many respiratory diseases. Accumulation of fat in the mediastinum and the abdominal cavities significantly alters the respiratory mechanics, and chest wall compliance, and this contributes to changes in the normal physiology of the lungs and exercise capacity.[6,9-13]

Therefore, the main objective of this study was to evaluate the effect of obesity on pulmonary functions among healthy non-smoking adults with no history of pulmonary disease.

MATERIALS AND METHODS

This cross-sectional study was carried out among 181 healthy adults aged between 20 and 60 years. The adults volunteered for master health check-up and those adult accompaniments of outpatients in the Department of Medicine in Karuna Medical College Hospital were selected as convenient and purposeful sample. The sample size was decided using a formula N = (Z(1-α))2PQ/L2. Since the available prevalence rate of obesity among adults from Kerala was ranging from 39% to 46%, a prevalence rate of 42% was taken into account. Then using the above formula, setting 99% confidence interval at 7% level of precision and 20% of non-response rate the sample size arrived was 230. The study participants who gave informed written consent were interviewed with a pre-designed, semi-structured questionnaire which comprised select sociodemographic details and information regarding smoking, cardiorespiratory illnesses, neuromuscular diseases enrolled, thoracic skeletal deformities, etc. Participants with known, respiratory, cardiovascular, and neuromuscular diseases, thoracic skeletal deformities, and history of smoking were excluded to examine the effect of adiposity on otherwise healthy lungs. Subjects fulfilling the inclusion criteria were enrolled in the study as consecutive samples. The study was conducted after obtaining institutional ethical clearance. Participants were categorized into three groups based on BMI classification for world's population. The most common metric used for assessing the prevalence of obesity is the BMI scale.

BMI

The most common metric used for assessing the prevalence of obesity is the BMI scale. BMI is calculated by dividing the weight of the subject in Kg by squared of height of the subject in meter scale. The height was measured in centimeters using stadiometer to the nearest 0.1 cm and body weight was measured in kilograms using a well calibrated adult using digital weighing machine to the nearest 0.1 kg in light indoor clothing without shoes. After calculating the BMI, the participants were categorized into three groups according to the WHO obesity classification for world's population based on BMI.[3]

Pulmonary function test: Spirometry is a commonly used method for detecting lung function that represents a measure of volume against time 14. ndd TrueFlow EasyOne™ diagnostic spirometer, made in Zurich Switzerland, is used to measure pulmonary functions. The test was performed after 1–2 h following breakfast. The individuals were made to sit comfortably and instruction was given in English or in local language. Individuals were asked to close the nostrils with thumb and index finger and were told to take a deep and deeper breath through his/her mouth and breath out with maximum effort through the mouth piece which is connected to the easy one spirometer. A long beep indicates completion of the test. The procedure was repeated until the spirometer displays "session complete" after at least three attempts. Individuals were given adequate rest in between the attempts. ndd EasyOne™ diagnostic spirometer was connected to the personal computer in which the EasyWare software 2.22.0.0 version was installed and the test results are obtained as hard copy. The data thus obtained were entered into excel sheet and subjected to analysis.

The following pulmonary variables were included in this study.

Forced vital capacity in liters (FVC)

The maximum volume of air can be exhaled with maximum forced expiratory effort from the maximum inspiration.

Forced expiratory volume in the first second in liters (FEV1)

The fraction of the FVC expired during the first second of a forced expiration.

FEV1/FVC

The ratio between FEV1 and FVC.

Forced expiratory flow 25–75%

The mean forced expiratory flow (FEF) between 25% and 75% of the FVC has also been known as the maximum mid-expiratory flow. This index is taken from the blow with the largest sum of FEV1 and FVC. It should be noted that it is highly dependent on the validity of the FVC measurement and the level of expiratory effort.[14]

Peak expiratory flow rate (PEFR)

PEF is usually obtained from flow-volume curve data. It is the maximum expiratory flow achieved from a maximum forced expiration, starting without hesitation from the point of maximal lung inflation, expressed in L•s−1.

Statistical analysis

Out of total 230 subjects enrolled in the study, 26 subjects (11%) withdrew the consent because of their time constraints to spend on the study. Out of remaining 204 study participants, 23 participants' (10%) data went on attrition due to inadequate output of the spirometry readings. Hence, the final sample available for analysis was 181 subjects (79%) ($n = 181$). Thus, collected data were entered into excel sheet and subjected to analysis mean, standard deviation, correlations, regressions, and differences among the obesity groups using suitable statistical tests of significance such as ANOVA, Pearson's test, and Turkey *post hoc* honestly significant difference (HSD), with the help of statistical software.

RESULTS

Out of 181 participants, 127 (70.2%) were male and 54 (29.8%) were female. Among the males majority (71.6%) and among females majority (64.8%) were from 41 to 60 years age group. Among 54 participants with BMI 18–24.9, around 60% were male and 40% were female. Among 82 participants with BMI 25–29.5%, around 72% were male and 28% were female. Similarly among the participant with BMI 30 and above, around 75% were male and 25% were female. The frequency distribution of the study participants according to their age, sex, and BMI is shown in Table 1.

The study participants were categorized according to BMI classification into three groups. A one-way ANOVA was conducted to compare the demographic data of the three BMI groups. There was no statistically significant difference in age, height among the three groups. However, the means of weight and BMI were significantly higher in overweight and obese group than normal weight subjects. The results are shown in Table 2.

A one-way between-subjects ANOVA was conducted to compare the effect of BMI on pulmonary functions in normal weight, overweight, and obese groups. There was a significant effect of BMI on FVC, FEV1, PEFR, and FEF25–75% at $P < 0.001$ level for the three groups. However, the FEV1/FVC did not show significant difference between the three groups. The results of one-way ANOVA are shown in Table 3.

As the one-way ANOVA showed significant differences in pulmonary variables, the *post hoc* comparisons using the Tukey HSD test were done to find out which group was significantly different from other groups. This test indicated that the mean score of FVC, FEV1, PEFR, and FEF25–75% for the obese group and overweight group was significantly different from the mean score for the normal weight group. However, the FEV1/FVC ratio did not show statistically significant differences in both overweight and obese groups when compared with normal weight group. And also, the mean score of overweight group was significantly different from obese group for all the pulmonary variables except FVC. The FVC of overweight group did not significantly differ from the obese group. The results of the Tukey HSD test are shown in Table 4.

Taken together these results suggest that obesity does have an effect on pulmonary function test. Specifically, our results suggest that overweight and obese conditions have an adverse effect on pulmonary function.

In the Phase II analysis, Pearson correlation test was done to find out the relationship of BMI with pulmonary variables. Pearson correlation test showed a strong negative correlation between BMI and pulmonary functions, at the level of 0.01 was observed. The results of Pearson correlation test are shown in Table 5.

In linear regression analysis, BMI was independent variable and FVC, FEV1, FEV1/FVC, FEF25–75%, and PEFR were dependent variables. BMI was a significant predictor of FVC, FEV1, FEF25–

Table 1: Frequency distribution of the study participants according to their demographic details

Variable	Males		Females		Total	
	Frequency	%	Frequency	%	Frequency	%
Age						
20–40 years	36	65.5	19	34.5	55	30.4
41–60 years	91	72.2	35	27.8	126	69.6
BMI						
18–24.9	32	59.3	22	40.7	54	29.8
25–29.9	61	74.4	21	25.6	82	45.3
30 and above	34	75.6	11	24.4	45	24.9

Table 2: Comparison demographic data of normal weight, overweight, and obese subjects

Variable	Normal weight group (body mass index=18–25)	Overweight group (body mass index=25.1–30)	Obese group (body mass index=30 and above)	F value	*P* value
Age	44.4±7.9	44.21±6.9	40.77±9.5	2.78	0.64
Height	165.9±7.5	166±6.5	166.9±5.9	0.31	0.73
Weight	63.1±8.6	75.4±6.9	92.06±11.2	135.64	<0.001**
Body mass index	22.8±1.77	27.34±1.48	32.9±2.8	324.11	<0.001**

**Significant *P* value at the *P*<0.001 level

Table 3: Comparison of pulmonary variables of normal weight, overweight, and obese subjects

Pulmonary variables	Normal weight group (BMI=18–25)	Overweight group (BMI=25.1–30)	Obese group (BMI=30 and above)	F value	*P* value
FVC (L)	3.27±0.74	2.83±0.5	2.59±0.3	17.39	<0.001**
FEV1(L)	2.79±0.64	2.41±0.44	2.18±0.48	17.70	<0.001**
FEV1/FVC	0.85±0.04	0.85±0.04	0.84±0.05	0.63	0.55**
FEF25–75% (L/S)	3.48±0.6	2.87±0.58	2.45±0.55	39.68	<0.001**
PEFR (L)	431.7±86.9	358.01±0.04	312.5±66.03	28.88	<0.001**

**Significant *P* value at *P*<0.001 level. BMI: Body mass index, FVC: Forced vital capacity, FEV: Forced expiratory volume, PEFR: Peak expiratory flow rate, FEF: Forced expiratory flow

Table 4: Comparison of all pulmonary variables between normal weight and overweight groups, normal weight and obese groups, and normal weight and obese groups

Variables	Independent variables pairs	Tukey HSD Q statistic	Tukey HSD *P* value	Tukey HSD inference
FVC	Normal weight versus overweight	5.96	0.001	*P*<0.01**
	Normal weight versus obese	8.09	0.001	*P*<0.01**
	Overweight versus obese	3.17	0.066	Insignificant
FEV1	Normal weight versus overweight	5.85	0.001	*P*<0.01**
	Normal weight versus obese	8.21	0.001	*P*<0.01**
	Overweight versus obese	3.17	0.045	*P*<0.05*
FEV1/FVC	Normal weight versus overweight	0.10	0.899	Insignificant
	Normal weight versus obese	1.41	0.573	Insignificant
	Overweight versus obese	1.44	0.561	Insignificant
PEFR	Normal weight versus overweight	7.47	0.001	*P*<0.01**
	Normal weight versus obese	10.49	0.001	*P*<0.01**
	Overweight versus obese	4.35	0.006	*P*<0.01**
FEV25–75%	Normal weight versus overweight	8.47	0.001	*P*<0.01**
	Normal weight versus obese	12.37	0.001	*P*<0.01**
	Overweight versus obese	5.46	0.001	*P*<0.01**

**Significant *P* value at *P*<0.00 level, *significant *P* value at *P*<0.05 level. FVC: Forced vital capacity, FEV: Forced expiratory volume, PEFR: Peak expiratory flow rate, FEF: Forced expiratory flow

Table 5: Correlation of pulmonary variables with body mass index in study subjects

Pulmonary variables	Body mass index	
	R value	*P* value
FVC	−0.355	<0.001**
FEV1	−0.361	<0.001**
FEV1/FVC	−0.080	0.2843
FEF25%–75%	−0.432	<0.001**
PEFR	−0.501	<0.001**

**Correlation is significant at 0.01 level. FVC: Forced vital capacity, FEV: Forced expiratory volume, PEFR: Peak expiratory flow rate, FEF: Forced expiratory flow

Table 6: Linear regression analysis of pulmonary variables with BMI

Dependent variables	Independent variable BMI		
	R^2 value	R value	*P* value
FVC	0.1260	0.35	<0.001**
FEV1	0.1305	0.35	<0.001**
FEV1/FVC	0.0064	0.08	0.28
FEF25%–75%	0.0187	0.432	<0.001**
PEFR	0.2519	0.501	<0.001**

**Significant *P* value at *P*<0.01 level. BMI: Body mass index, FVC: Forced vital capacity, FEV: Forced expiratory volume, PEFR: Peak expiratory flow rate, FEF: Forced expiratory flow

75%, and PEFR (*P* < 0.000). Linear regression analysis results are given in Table 6.

Linear regression analysis for FVC, FEV1, FEV1/FVC, FEF25%–75%, and PEFR against BMI is shown in [Figures 1–5]. A significant negative correlation was found, between pulmonary variables and BMI, except for FEV1/FVC ratio. Pearson correlation coefficient and linear regression analysis indicate that pulmonary variables except FEV1/FVC ratio tend to decrease with increasing BMI.

DISCUSSION

The major findings of this study were statistically significant reduction in FVC, FEV1, FEF25%–75%, and PEFR in both overweight and obese subjects when compared to normal weight individuals. The results of Tukey *post hoc* test showed statistically significant reduction in pulmonary variables in overweight and obese group than in normal weight group. And also, it showed significant reduction of FEV1, FEV1/FVC, FEF25%–75%, and PEFR in obese when compared with overweight. However, FVC did not show any difference between overweight and obese groups. These findings explain that even moderate increase in BMI can cause reduction of FVC in overweight subjects.

The present study showed statistically negative correlation of FVC, FEV1, FEF25%–75%, and PEFR with BMI. The FEV1/FVC showed negative correlation of BMI, but it did not show statistical significance.

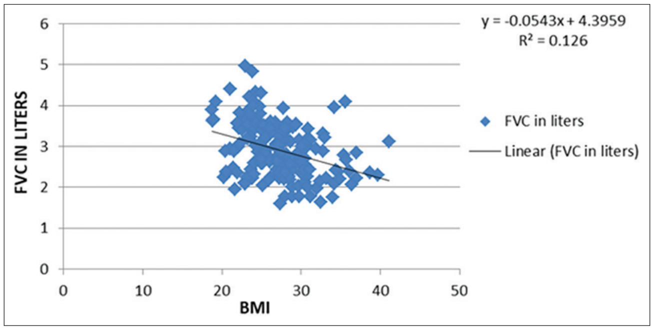

Figure 1: Linear regression analysis for forced vital capacity against body mass index

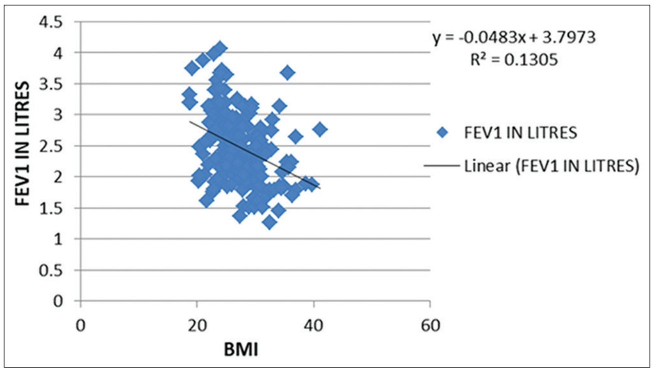

Figure 2: Linear regression analysis for forced expiratory volume 1 against body mass index

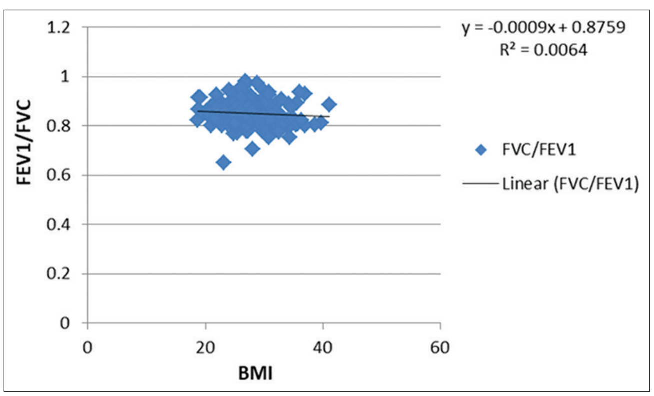

Figure 3: Linear regression analysis for forced expiratory volume 1/forced vital capacity against body mass index

The finding of a reduction in FVC and FEV1 with increasing baseline BMI is in agreement with several cross-sectional studies that found reduction in pulmonary function and negative associations of BMI with FVC and FEV1.[15-17] A study conducted in China found significant reduction in FVC in obese subjects but not in FEV1, FEV1/FVC, PEF, and FEF25–75%.[18]

Some studies conducted earlier showed that waist circumference, waist–hip ratio, and waist–height

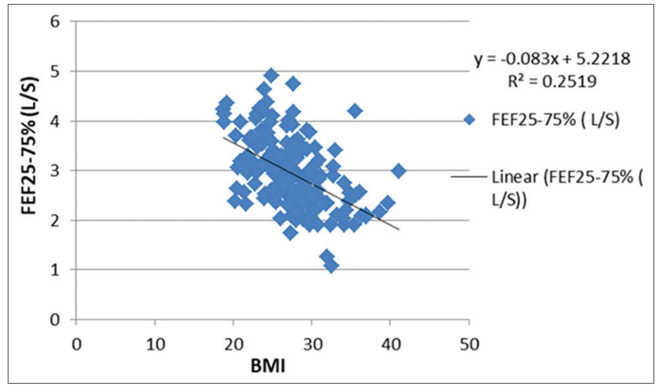

Figure 4: Linear regression analysis for forced expiratory flow 25%–75% against body mass index

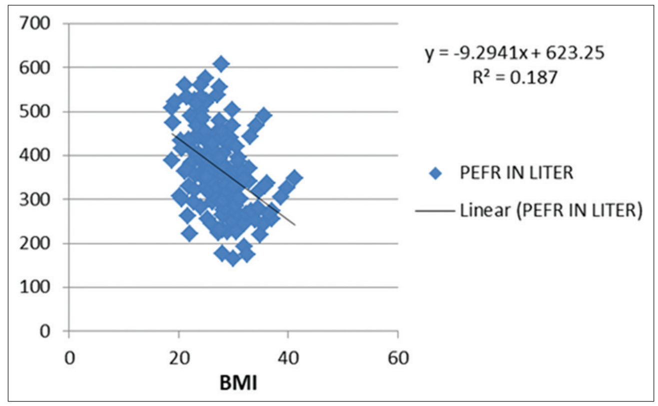

Figure 5: Linear regression analysis for peak expiratory flow rate against body mass index

ratio were better markers that can be used clinically to assess the impact of obesity on pulmonary function rather than that of BMI. These studies were conducted among 18–20 years old young subjects.[19,20]

Longitudinal studies conducted in the past, found strong associations between lung function and BMI. FVC and FEV1 generally decreased over a 10-year period both with higher baseline BMI and with increasing BMI over 10 years of follow-up[21] and other longitudinal studies found that weight gain is associated with more rapid loss of lung function.[22-24] Weight loss is the key intervention in managing the patients with obesity-related lung dysfunction. Studies suggest that weight loss can reverse many of the alterations in pulmonary function produced by obesity.[25]

In the present study, FEV1/FVC ratio did not show significant differences between normal weight and overweight and obese subjects. However, the use of spirometry to evaluate lung function in morbidly obese subjects revealed a proportional reduction in FVC and FEV1, suggesting the occurrence of restrictive lung disease.[26,27]

The reduction in FEV1 and FVC appears to be directly associated with the degree of obesity in morbidly obese subjects with more severe restrictions. However, obesity has little direct effect on airway caliber. The FEV1/FVC ratio is generally well preserved or elevated even in morbidly obese individuals, indicating that FEV1 and FVC are affected at the same rate.[21]

In the present study, FEF25–75% is significantly lower in overweight and obese group than in normal weight group. The FEF25–75% is the most commonly cited indicator of small airway obstruction. However, FEF25–75% measurements can vary markedly and change in proportion to the FVC.

In the present study, the PEFR is significantly lower in overweight and obese groups than in normal weight group. A reduction in expiratory flows in an obese individual is unlikely to indicate bronchial obstruction unless the flow measurements have been normalized for the reduction in FVC.[28]

Most reductions in FEF25–75% and FEF75% measurements in the absence of classically defined airways obstruction using FEV1/FVC data result from reduced lung volume rather than from airways disease. A study conducted by Quanjer *et al*. who suggested that maximum mid-expiratory flow (FEF25%–75%) and flow toward the end of the forced expiratory maneuver (FEF75%) does not contribute usefully to clinical decision-making.[29]

Obtaining an additional measurement of thin-layer chromatography (TLC) is more useful than FEF25–75%, PEFR in diagnosing obstructive lung disease in subjects with normal FEV1/FVC and low FVC when clinicians suspect obstructive lung disease.[30]

Limitations of the study

First, the present study was a cross-sectional study; we could only conclude that increased BMI reduces pulmonary functions. A prospective study will be worthwhile to understand the effect of weight loss on pulmonary functions in obese subjects. Second, other obesity markers such as body fat percentage, waist circumference, waist–hip ratio, and waist–height ratio were not correlated with pulmonary functions. Third, the low FEF25%–75% and PEFR values need additional measurement of TLC to evaluate the restrictive or obstructive nature of spirometry in obese subjects.

CONCLUSION

The present study suggests that higher BMI is associated with impaired pulmonary function and demonstrated reduced FVC, FEV1, FEF25–75%, and PEFR in overweight and obese subjects, when compared to normal weight subjects. These adverse effects of increasing BMI on pulmonary functions were observed even in overweight subjects. Reduction in FVC, accompanied by FEV1, was the most representative findings among the subjects, suggesting the presence of a restrictive respiratory pattern associated with obesity. It might be due to decrease in lung and chest wall compliance and increase in work of breathing. However, these alterations in pulmonary function, due to excess adiposity, might be reversible. Hence, weight loss can improve pulmonary function and exercise capacity.

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REFERENCES

1. GBD 2017 Risk Factor Collaborators. Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990-2017: A systematic analysis for the Global Burden of Disease Study 2017. Lancet 2018;392:1923-94.
2. World Health Organization. Obesity and Overweight. Geneva: World Health Organization; 2018.
3. World Health Organization. Global Database on Body Mass Index. BMI Classification. Geneva: World Health Organization; 2018.

4. Bahia L, Aguiar LG, Villela N, Bottino D, Godoy-Matos AF, Geloneze B, *et al*. Relationship between adipokines, inflammation, and vascular reactivity in lean controls and obese subjects with metabolic syndrome. Clinics (Sao Paulo) 2006;61:433-40.
5. Faintuch J, Horie LM, Schmidt VD, Barbeiro HV, Barbeiro DF, Soriano FG, *et al*. Obesity, inflammation, vascular reactivity, and cardiocirculatory events. Clinics (Sao Paulo) 2007;62:357-8.
6. Dixon AE, Peters U. The effect of obesity on lung function. Expert Rev Respir Med 2018;12:755-67.
7. Beuther DA, Sutherland ER. Overweight, obesity, and incident asthma: A meta-analysis of prospective epidemiologic studies. Am J Respir Crit Care Med 2007;175:661-6.
8. Guerra S, Sherrill DL, Bobadilla A, Martinez FD, Barbee RA. The relation of body mass index to asthma, chronic bronchitis, and emphysema. Chest 2002;122:1256-63.
9. Faintuch J, Souza SA, Valezi AC, Sant'Anna AF, Gama-Rodrigues JJ. Pulmonary function and aerobic capacity in asymptomatic bariatric candidates with very severe morbid obesity. Rev Hosp Clin Fac Med Sao Paulo 2004;59:181-6.
10. Koenig SM. Pulmonary complications of obesity. Am J Med Sci 2001;321:249-79.
11. Ladosky W, Botelho MA, Albuquerque JP. Chest mechanics in morbidly obese non-hypoventilated patients. Respir Med 2001;95:281-6.
12. Lotti P, Gigliotti F, Tesi F, Stendardi L, Grazzini M, Duranti R, *et al*. Respiratory muscles and dyspnea in obese nonsmoking subjects. Lung 2005;183:311-23.
13. Rasslan Z, Junior RS, Stirbulov R, Fabbri RM, Lima CA. Evaluation of pulmonary function in Class I and II obesity. J Bras Pneumol 2004;30:508-14.
14. Miller MR, Hankinson J, Brusasco V, Burgos F, Casaburi R, Coates A, *et al*. Standardisation of spirometry. Eur Respir J 2005;26:319-38.
15. Santana H, Zoico E, Turcato E, Tosoni P, Bissoli L, Olivieri M, *et al*. Relation between body composition, fat distribution, and lung function in elderly men. Am J Clin Nutr 2001;73:827-31.
16. Banerjee J, Roy A, Singhamahapatra A, Dey PK, Ghosal A, Das A. Association of Body Mass Index (BMI) with lung function parameters in non-asthmatics identified by spirometric protocols. J Clin Diagn Res 2014;8:12-4.
17. Catherine AP, Vinodha R. Effect of body mass index on lung volumes. Int J Curr Res 2015;7:20187-92.
18. Wang S, Sun X, Hsia TC, Lin X, Li M. The effects of body mass index on spirometry tests among adults in Xi'an, China. Medicine (Baltimore) 2017;96:e6596.
19. Farooq SN, Azeem MA, Serafi AH, Ahmed A, Mustafa SM, Rizvi MI. Effect of season on contractile properties of immobilized gastrocnemius muscles of uromastix hardwick-II. Med Res Chron 2015;2:135-47.
20. Koraddi ST, Bagali S, Aithala M. Effect of body fat distribution on pulmonary functions in young healthy obese students. J Krishna Inst Med Sci Univ 2015;4:18-26.
21. Thyagarajan B, Jacobs DR Jr., Apostol GG, Smith LJ, Jensen RL, Crapo RO, *et al*. Longitudinal association of body mass index with lung function: The CARDIA study. Respir Res 2008;9:31.
22. Wang ML, McCabe L, Petsonk EL, Hankinson JL, Banks DE. Weight gain and longitudinal changes in lung function in steel workers. Chest 1997;111:1526-32.
23. Chen Y, Horne SL, Dosman JA. Body weight and weight gain related to pulmonary function decline in adults: A six year follow up study. Thorax 1993;48:375-80.
24. Bottai M, Pistelli F, Di Pede F, Carrozzi L, Baldacci S, Matteelli G, *et al*. Longitudinal changes of body mass index, spirometry and diffusion in a general population. Eur Respir J 2002;20:665-73.
25. Brazzale DJ, Pretto JJ, Schachter LM. Optimizing respiratory function assessments to elucidate the impact of obesity on respiratory health. Respirology 2015;20:715-21.
26. Melo LC, Silva MA, Calles AC. Obesity and lung function: A systematic review. Einstein (Sao Paulo) 2014;12:120-5.
27. Carpio C, Santiago A, De García Lorenzo A, Alvarez-Sala R. Changes in lung function testing associated with obesity. Nutr Hosp 2014;30:1054-62.
28. Salome CM, King GG, Berend N. Physiology of obesity and effects on lung function. J Appl Physiol (1985) 2010;108:206-11.
29. Quanjer PH, Weiner DJ, Pretto JJ, Brazzale DJ, Boros PW. Measurement of FEF25-75% and FEF75% does not contribute to clinical decision making. Eur Respir J 2014;43:1051-8.
30. Lee H, Chang B, Kim K, Song WJ, Chon HR, Kang HK, *et al*. Clinical utility of additional measurement of total lung capacity in diagnosing obstructive lung disease in subjects with restrictive pattern of spirometry. Respir Care 2016;61:475-82.